Introducing Environmental MCDA

by Thomas P. Seager and Seth Tuler

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MCDA in USACE

Case study in contaminated sediments

New projects: NOAA, NHDES

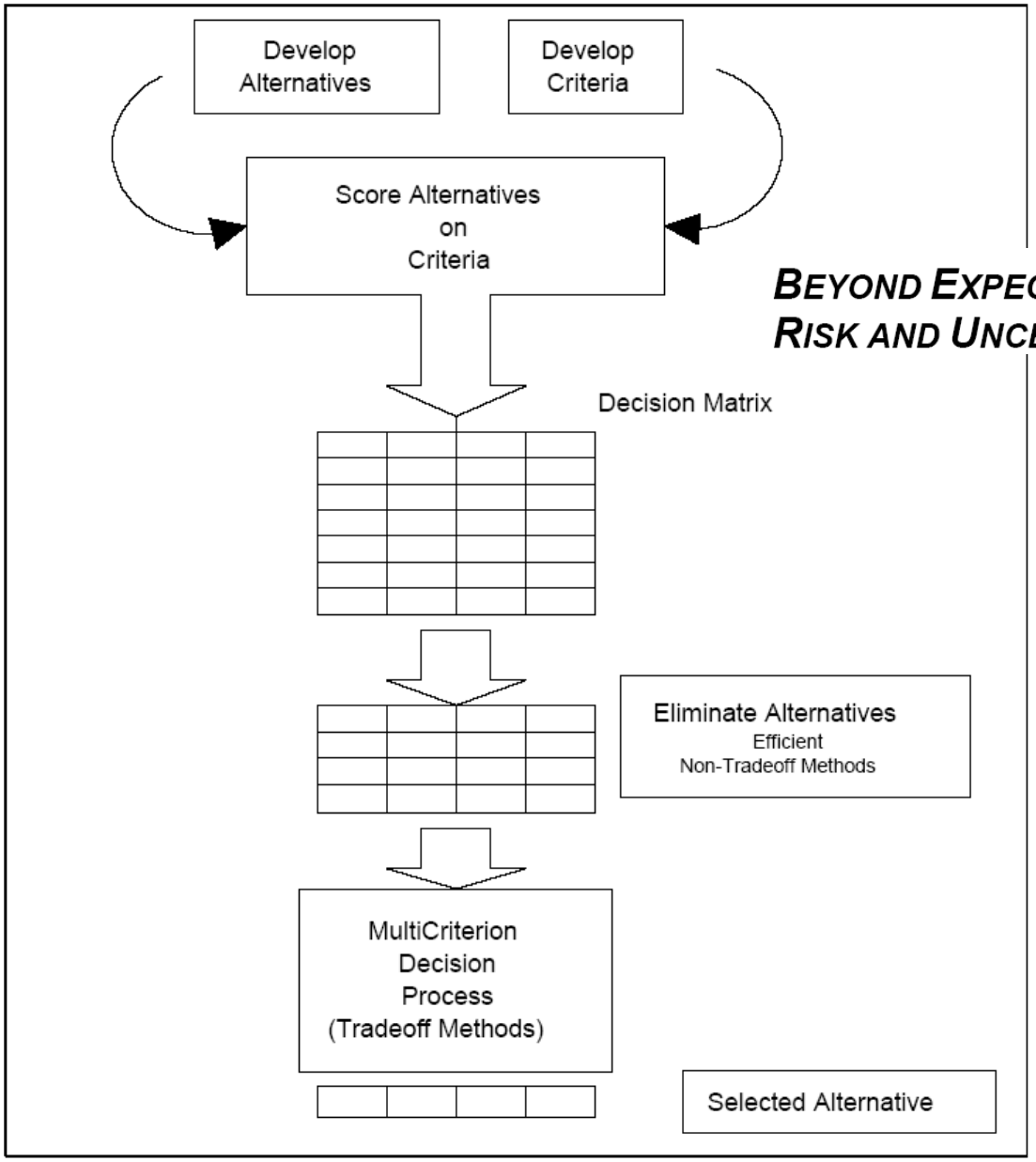

FIGURE V-1
STEPS IN THE MULTICRITERION DECISION PROCESS

BEYOND EXPECTED VALUE: MAKING DECISIONS UNDER RISK AND UNCERTAINTY

U.S. Army Corps of Engineers
Institute for Water Resources
Casey Building
7701 Telegraph Road
Alexandria, VA 22315

Task Order #27
Contract No. DACW72-99-D-0001

September 2002

by

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Trade-Off Analysis Planning and Procedures Guidebook

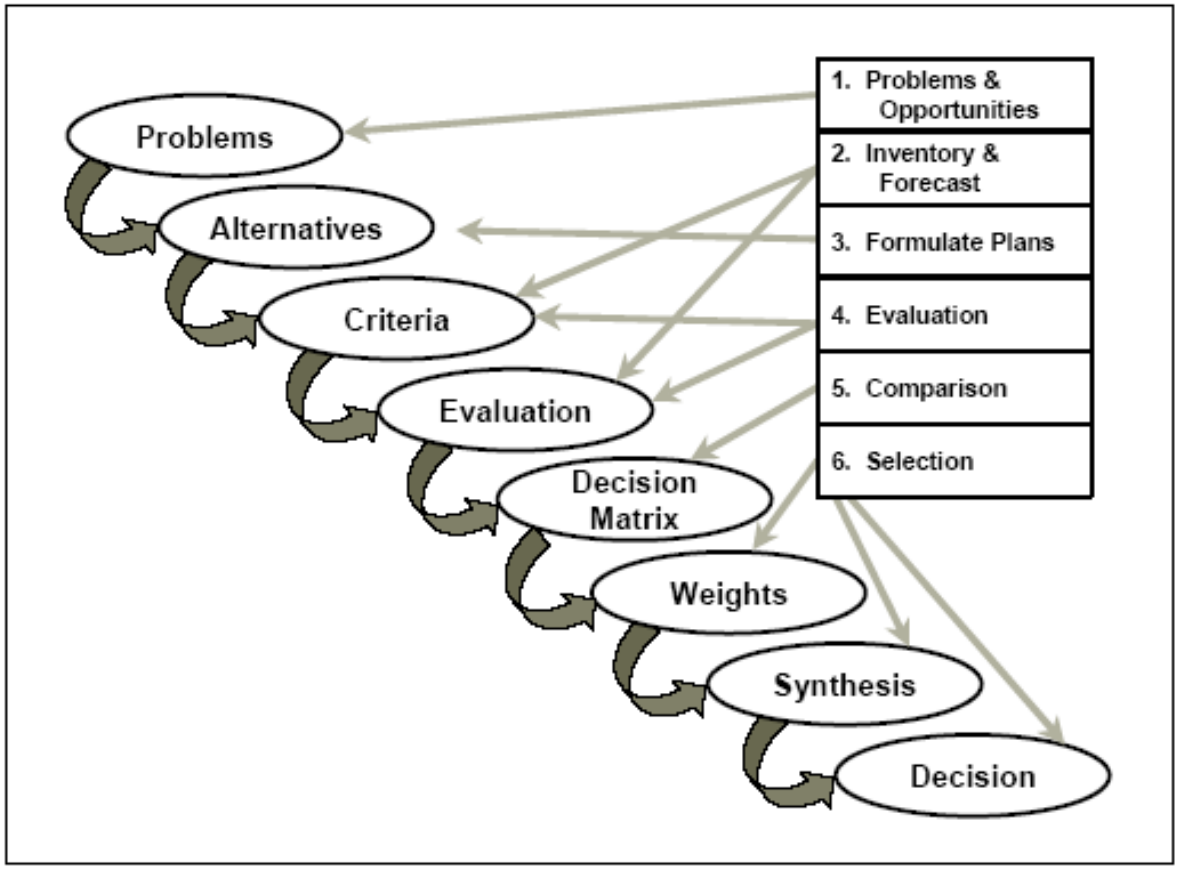

Figure 3: Relation of Planning Process to Multicriteria Decision Support Framework

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Task Order #20
Contract No. DACW72-00-D-0001

April 2002

TABLE 3: DECISION MATRIX

	Net NED Benefits	First Cost	Aquatic Habitat	Upland Habitat
Plan 1	$477,000	$15,663,000	Slight decrease	+45HUs
Plan 2	$196,000	$19,610,000	Modest increase	+40HUs
Plan 3	$260,000	$13,450,000	No change	+30HUs
Plan 4	$294,000	$17,403,000	Slight increase	+60HUs

TABLE 4: TRANSFORMED DECISION MATRIX

	Net Benefits	First Cost	Aquatic Habitat	Upland Habitat
Plan 1	1	2	4	2
Plan 2	4	4	1	3
Plan 3	3	1	3	4
Plan 4	2	3	2	1

TABLE 7: DECISION MATRIX NORMALIZED BY PERCENTAGE OF MAXIMUM

	Net Benefits	First Cost	Aquatic Habitat	Upland Habitat
Plan 1	1.0000	0.8587	0.2500	0.7500
Plan 2	0.4109	0.6859	1.0000	0.6667
Plan 3	0.5451	1.0000	0.5000	0.5000
Plan 4	0.6164	0.7729	0.7500	1.0000

TABLE 8: DECISION MATRIX NORMALIZED BY PERCENTAGE OF RANGE

	Net Benefits	First Cost	Aquatic Habitat	Upland Habitat
Plan 1	1.0000	0.5502	0.0000	0.5000
Plan 2	0.0000	0.0000	1.0000	0.3333
Plan 3	0.2278	1.0000	0.3333	0.0000
Plan 4	0.3488	0.2769	0.6667	1.0000

TABLE 9: DECISION MATRIX NORMALIZED BY PERCENTAGE OF TOTAL

	Net Benefits	First Cost	Aquatic Habitat	Upland Habitat
Plan 1	0.3888	0.2588	0.1000	0.2571
Plan 2	0.1597	0.2067	0.4000	0.2286
Plan 3	0.2119	0.3014	0.2000	0.1714
Plan 4	0.2396	0.2330	0.3000	0.3429

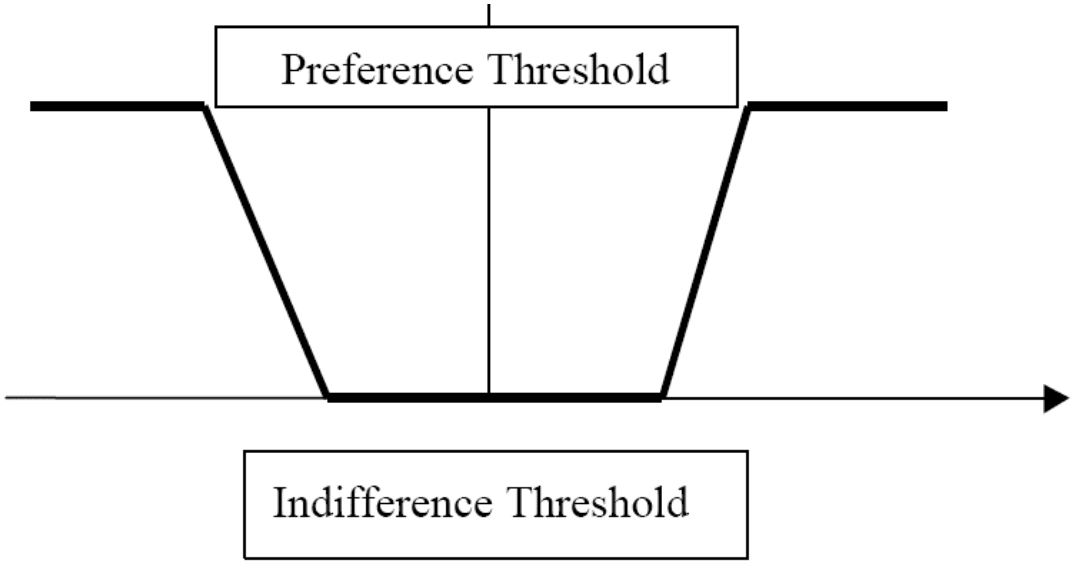
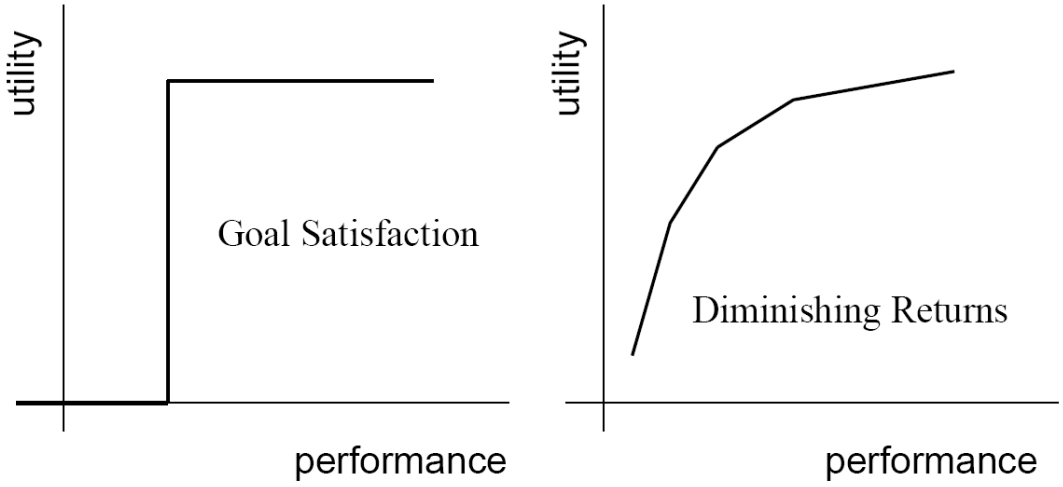


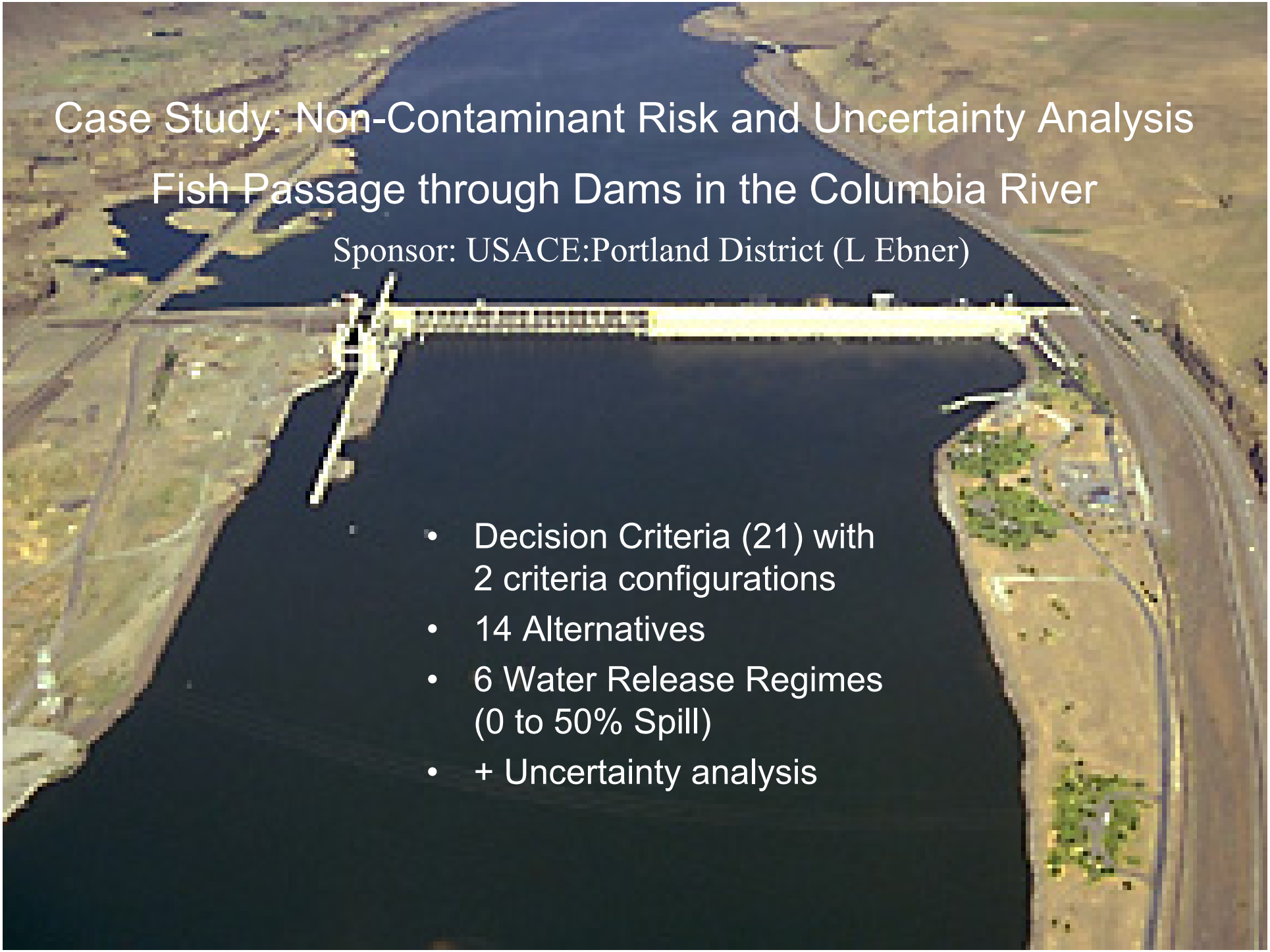
FIGURE VI Intra-Criteria Modeling: Preference Functions



MCDA as Alternative to Weight of Evidence Evaluation

Sponsor: USACE-ERDC (T Bridges)

- Invertebrates
  - Freshwater mussels
- Fish
  - Largemouth Bass
  - Bluegill
  - American Eel
- Birds
  - Great blue heron
  - Belted kingfisher
  - Osprey
- Mammals
  - Raccoon
  - Mink



Case Study: Non-Contaminant Risk and Uncertainty Analysis

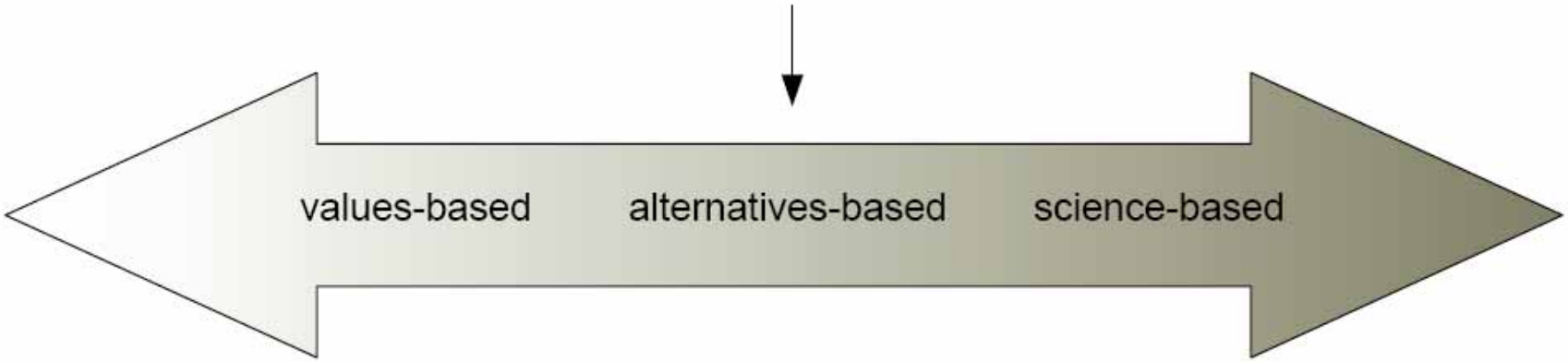
Fish Passage through Dams in the Columbia River

Sponsor: USACE:Portland District (L Ebner)

- Decision Criteria (21) with 2 criteria configurations
- 14 Alternatives
- 6 Water Release Regimes (0 to 50% Spill)
- + Uncertainty analysis

Public Participation

Stakeholder values meet expert science?



Democratic

Voter-driven

Bureaucratic

Expert-driven

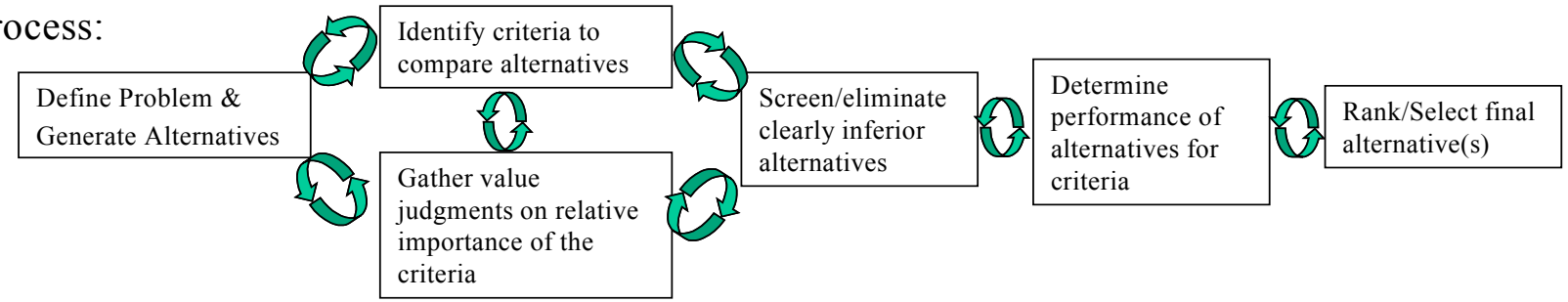
People:

Policy Decision Maker(s)

Scientists and Engineers

Stakeholders (Public, Business, Interest groups)

Process:



Tools:

Environmental Assessment/Modeling (Risk/Ecological/Environmental Assessment and Simulation Models)

Decision Analysis (Group Decision Making Techniques/Decision Methodologies and Software)

MULTI-CRITERIA DECISION ANALYSIS: A FRAMEWORK FOR MANAGING CONTAMINATED SEDIMENTS

Levner, E., Linkov, I., Proth, J.M., eds.
"Strategic Management of Marine Ecosystems,"
Kluwer, Amsterdam 2004 (in press).

Stakeholders	Define alternatives & criteria	Make measure-ments	Choose decision aid	Provide preference information	Form draft solution(s)	Make final decision
DMs	X		(X)	X		X
Interest groups	X			(X)		
Experts	X	X				
Planners	X	(X)	X		X	

Figure 1. Phases and stakeholder participation in environmental multicriteria decision processes.

Table 2. Final set of criteria in Savonlinna waste treatment plant application

Category	Criteria
Economy	g_1 = operating costs
	g_2 = building costs
	g_3 = transportation costs
Technology	g_4 = manageability of plant waters
	g_5 = linking with the existing infrastructure
Environment	g_6 = effects on ground water
	g_7 = effects on surface water
	g_8 = ecological effects
	g_9 = effects on the landscape
Man and the built-up environment	g_{10} = recreational use
	g_{11} = effects on the standards of housing
	g_{12} = cultural history
	g_{13} = health
	g_{14} = noise

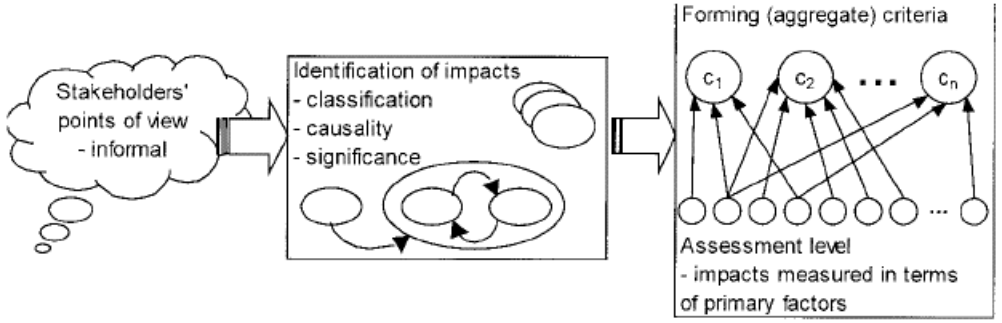
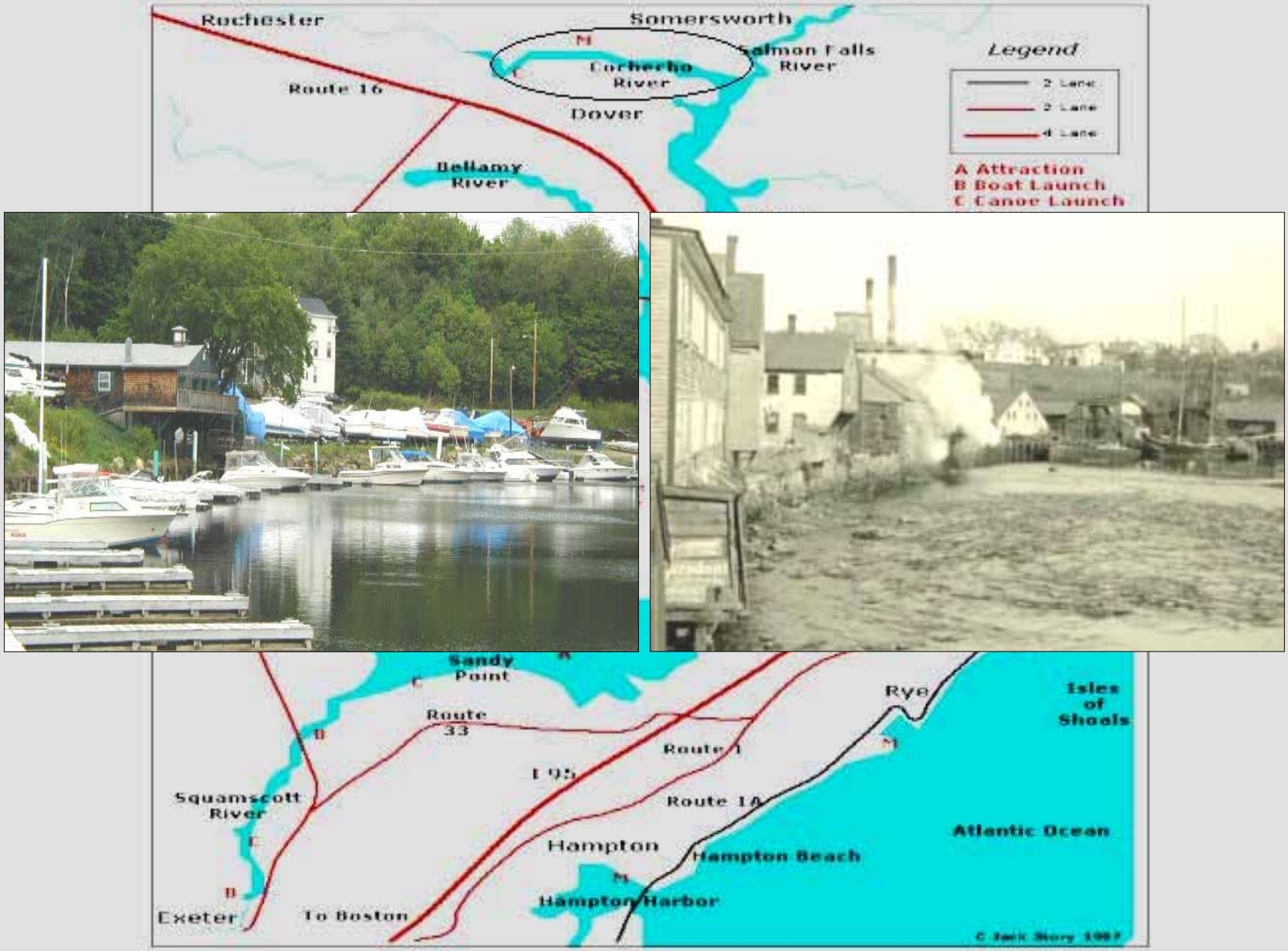


Figure 2. From stakeholders' points of view to identification of impacts and forming aggregate criteria.



Map is courtesy of Dover Chamber of Commerce Website

Alternatives Considered

Alternatives	Cost	Location	Safety	Effect on the Environment	Other
Turnkey Landfill					Privately owned landfill refused to accept sediments.
Ocean Dumping			Unsafe because of level of contaminants	Unacceptable because of level of contaminants	
Upland Disposal Sites Along the River		Land was undisturbed (in its natural state) or unsuitable (e.g. steep slopes)		Land was undisturbed (in its natural state) or unsuitable (e.g. steep slopes)	
Secure landfill site in Maine	Transportation costs were too high				
Abandoned Landfill Remediation (Superfund Site)					Contaminants were not suitable for this process
FORMER DOVER PUBLIC WORKS/ LANDFILL SITE (THIS SITE WAS CHOSEN)	Reasonable. Costs of upkeep and monitoring were acceptable	Close to the river (minimize risk to public of traveling with the contaminants), geography considered suitable for this type of project	Waiver needed to build disposal cell.	Officials say there will be minimal effect. Others are skeptical	

Industrial Ecology of Contaminated Sediments

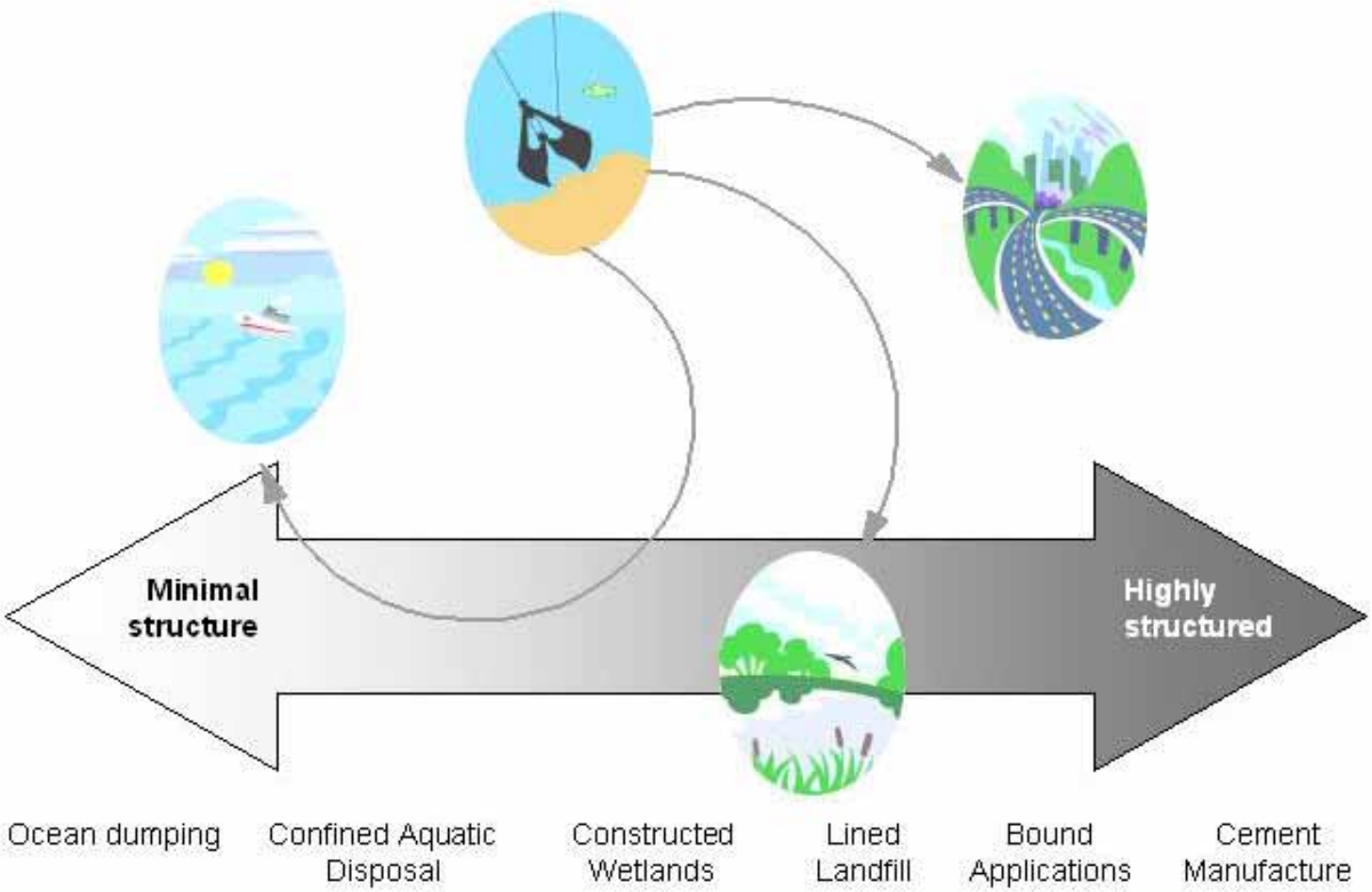


Table 2: Expert Performance Assessment of Alternatives

Alternative	Cost ($/cy)	Environmental Quality	Ecological Habitat (acres)	Human Habitat (acres)
Cement Manufacture	$30 *+3.0*	High *+2.0*	0 *-1.0*	0 *-1.0*
Flowable Fill	$55 *+1.0, -2.0*	Medium *-2.0*	0 *-1.0*	0 *-1.0*
Wetlands Restoration	$75 *-1.0*	High *+2.0*	+10 *+3.0*	0 *-1.0*
Upland Disposal Cell	$40 *+2.0, -1.0*	Medium *-2.0*	0 *-1.0*	+4 *+3.0*

Notes: Expert assessment determined the performance of each of the four salient criteria that stakeholders' identified as important. The actual alternative planned for use in the Cocheco River Project is the Upland Disposal Cell. Dominance rankings are given in Italics according to the number of clearly inferior (positive) or superior (negative) alternatives.

Table 3: Criteria Weightings of Typical Stakeholder Groups

	Human Habitat	Ecological Habitat	Env Quality	Cost	1st Choice	2nd Choice
Human Health (3)	0.5	0.1	0.25	0.15	Upland Cap +0.6, -0.25	Cement +0.32, -.20
Eco/Env (6)	0.2	0.3	0.4	0.1	Wetland +0.57, -0.17	Cement +0.37, -0.17
Balanced (2)	0.25	0.25	0.25	0.25	Cement +0.42, -0.17	Upland Cap +0.42, -0.33 Wetland +0.42, -0.33
Cost Group (1)	0.25	0.05	0.1	0.6	Cement +0.67, -0.10	Upland Cap +0.65, -0.28

Note: The numbers in parentheses indicate the number of respondents in each group. Positive and negative flows are separated by commas below the name of the preferred alternatives.

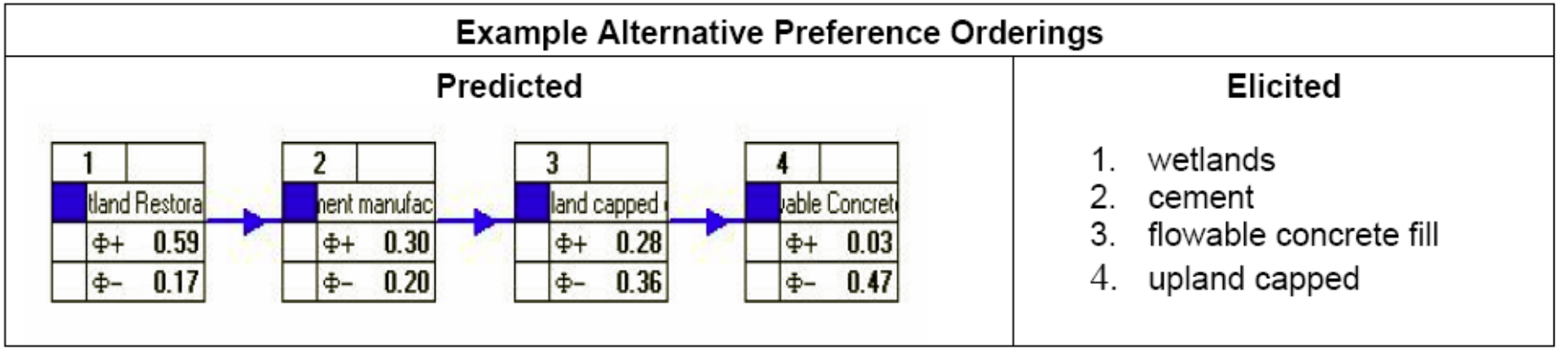


Figure 3. Based on individual preference functions, Decision Lab can predict the order in which any stakeholder would prefer available alternatives using PROMETHEE. Predicted results for all stakeholders were compared to the actual ordering of alternatives elicited from stakeholder inspection of the performance table given to stakeholders during the verification process.

Coupling Public Participation and Expert Judgment for Assessment of Innovative Contaminated Sediment Technologies

Thomas P. Seager[1*], Shannon H. Rogers[2], Kevin H. Gardner[3], Igor Linkov[4], Richard Howarth[5]

[1] School of Civil Engineering, Purdue University
[2] Industrial Economics, Inc.
[3] Center for Contaminated Sediments Research, University of New Hampshire
[4] Cambridge Environmental, Inc., Linkov@CambridgeEnvironmental.com
[5] Environmental Studies Program, Dartmouth College

TABLE 14: FIXED POINT SCORING EXAMPLES

	Decimal	Points	Weight (%)
Net Benefits	0.15	15	15
First Cost	0.30	30	30
Aquatic Habitat	0.15	15	15
Upland Habitat	0.40	40	40
Total	1.00	100	100

TABLE 16: NAÏVE APPROACH

	Ordinal Ranking	Importance Points	Cardinal Weights
Net Benefits	4	1	1/10
First Cost	2	3	3/10
Aquatic Habitat	3	2	2/10
Upland Habitat	1	4	4/10
Sum	10	10	1

lowest level — highest level

1 2 3 4 5 6 7 (circle one)

Most important — Least important

1 2 3 4 5

|___|___|___|___|

Figure 4: Likert Scale Examples

	Circle one
Net benefits is (more, equally, **less**) important than cost by a factor of	2 3 **4** 5 6 7 8 9
Net benefits is (more, **equally**, less) important than aquatic habitat by a factor of	2 3 4 5 6 7 8 9
Net benefits is (more, equally, **less**) important than upland habitat by a factor of	2 3 4 5 6 7 **8** 9
Cost is (**more**, equally, less) important than aquatic habitat by a factor of	2 3 **4** 5 6 7 8 9
Cost is (more, equally, **less**) important than upland habitat by a factor of	2 **3** 4 5 6 7 8 9
Aquatic habitat is (more, equally, **less**) important than upland habitat by a factor of	2 3 4 5 6 7 **8** 9

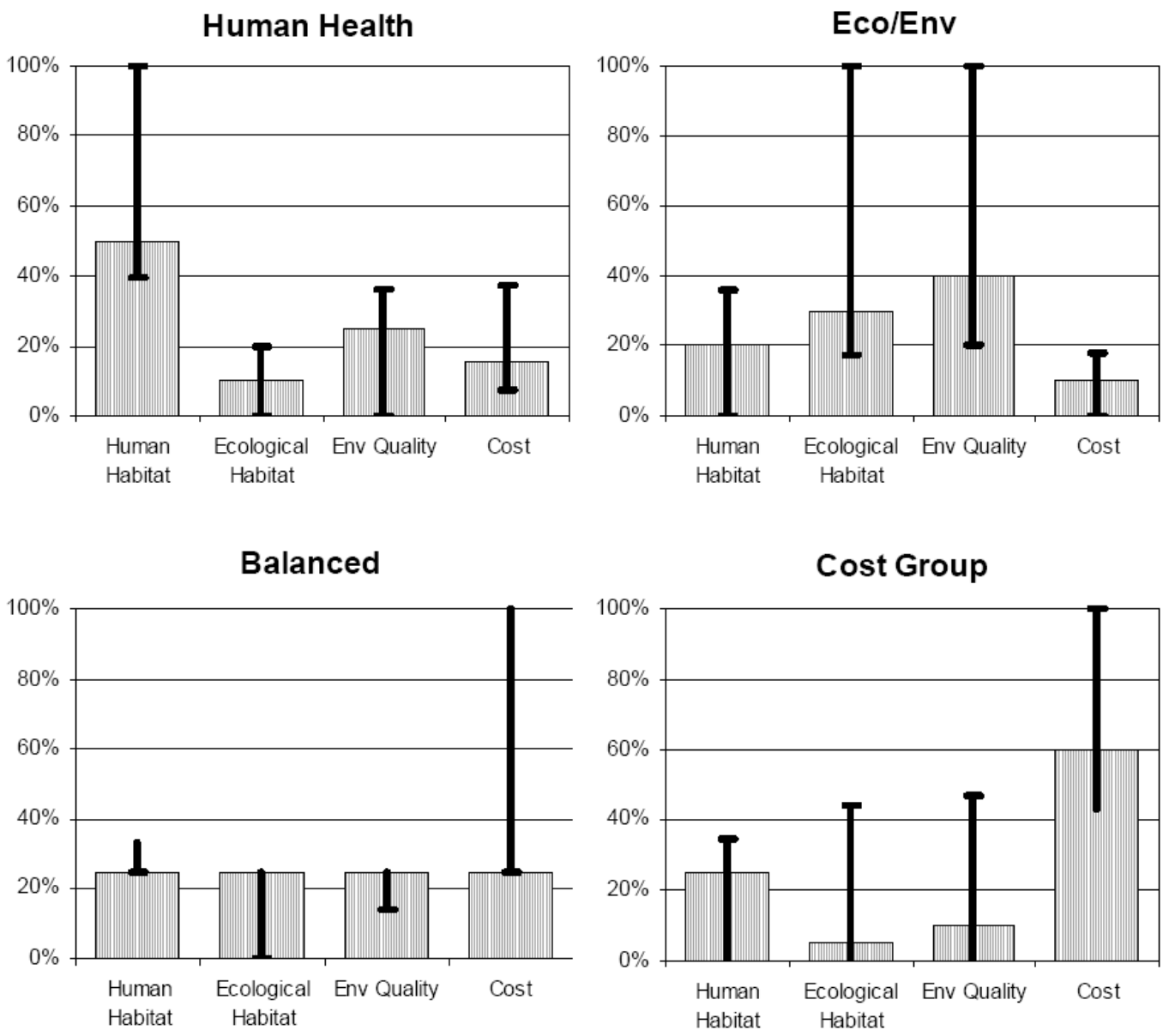


Figure 5: Stability intervals (represented as error bars) indicate the range of criteria weights over which the first two predicted preference orderings are unchanged. Upper bounds are indicative of the extent to which a criterion can be overweighted (at the equal expense of other criteria) without

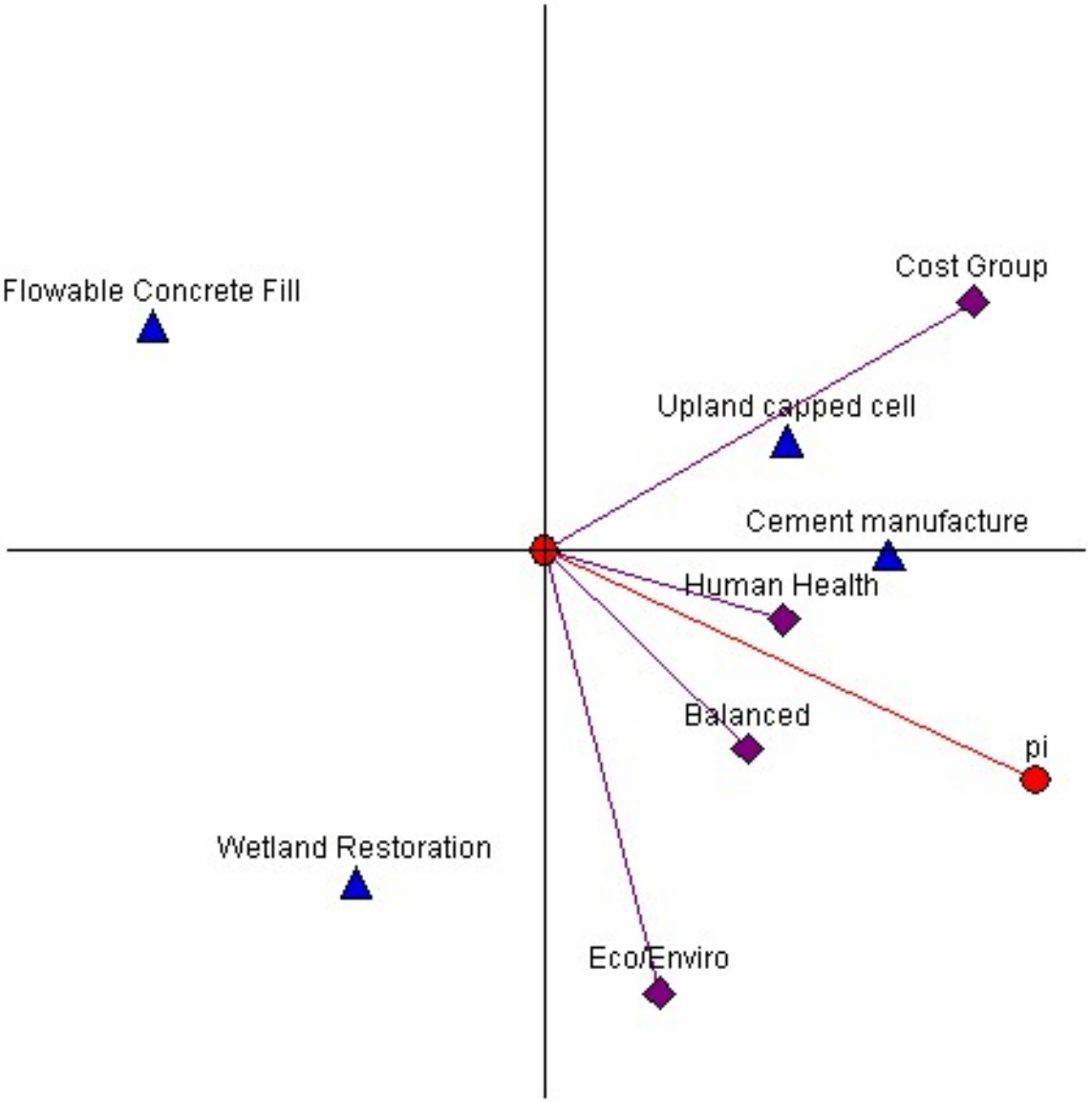


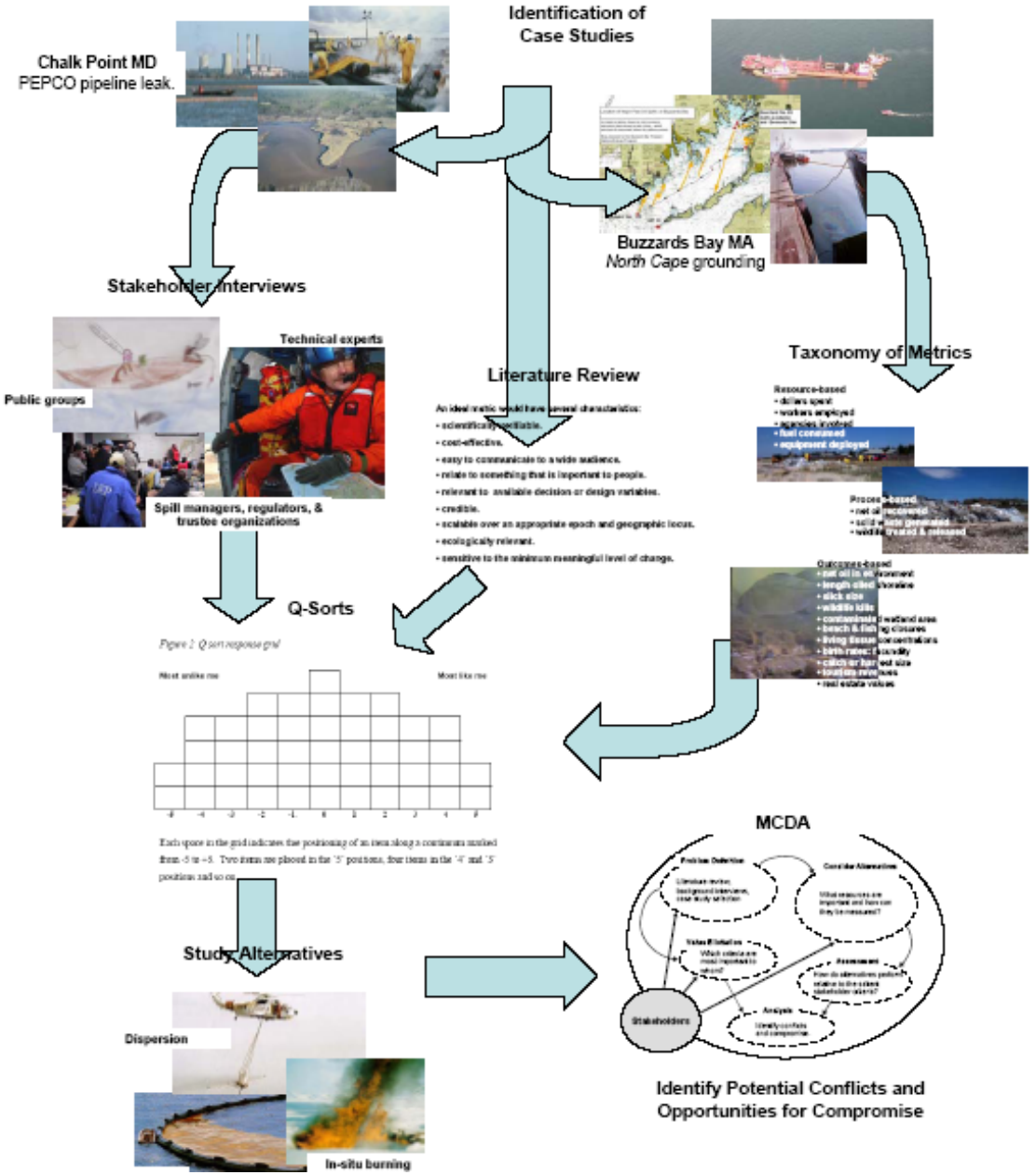
Figure 4: GAIA Plane analysis graphically depicts the relation between different stakeholder groups (diamonds) and the alternatives they are expected to prefer (triangles). In general, the groups that have the greatest potential for disagreement are represented by axes that are pointing away from one another. The "pi" axis is an average of all groups, representing the consensus if all groups are counted equally.

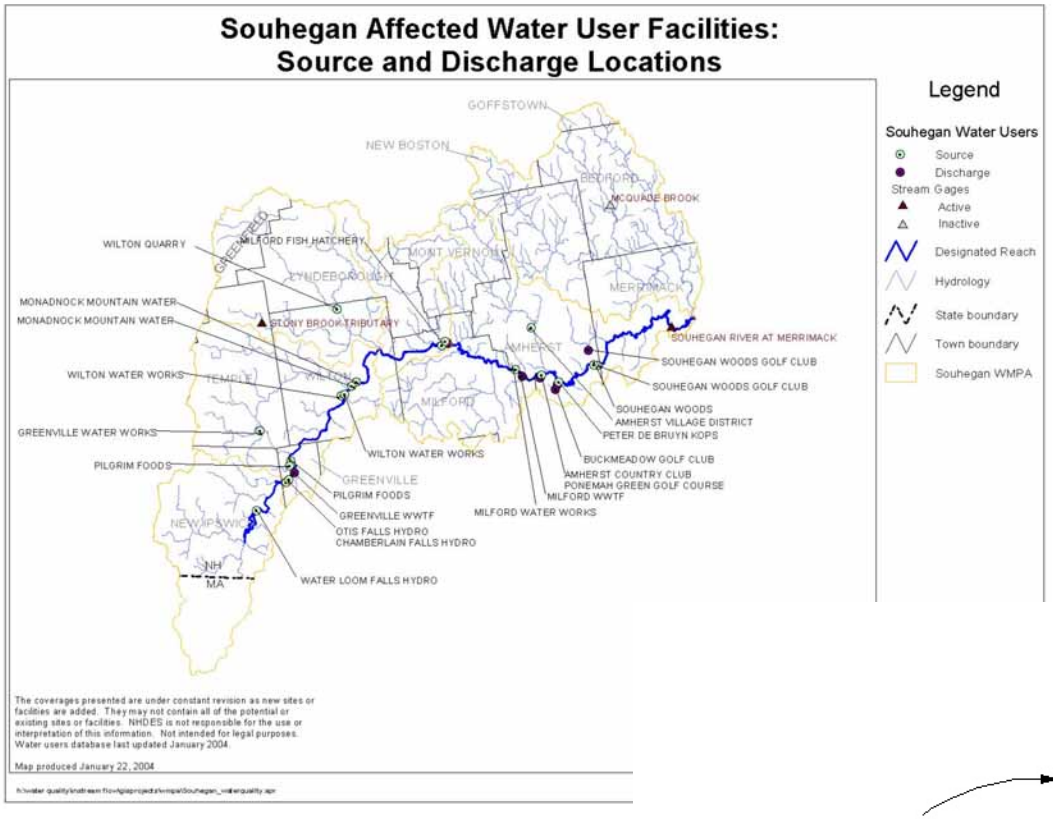
Funding provided by the
Coastal Response Research Center
www.crrc.unh.edu

Coastal Response Research Center

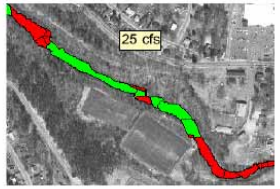
Performance Metrics for Oil Spill Response, Recovery & Restoration: Understanding Stakeholder & Expert Perspectives

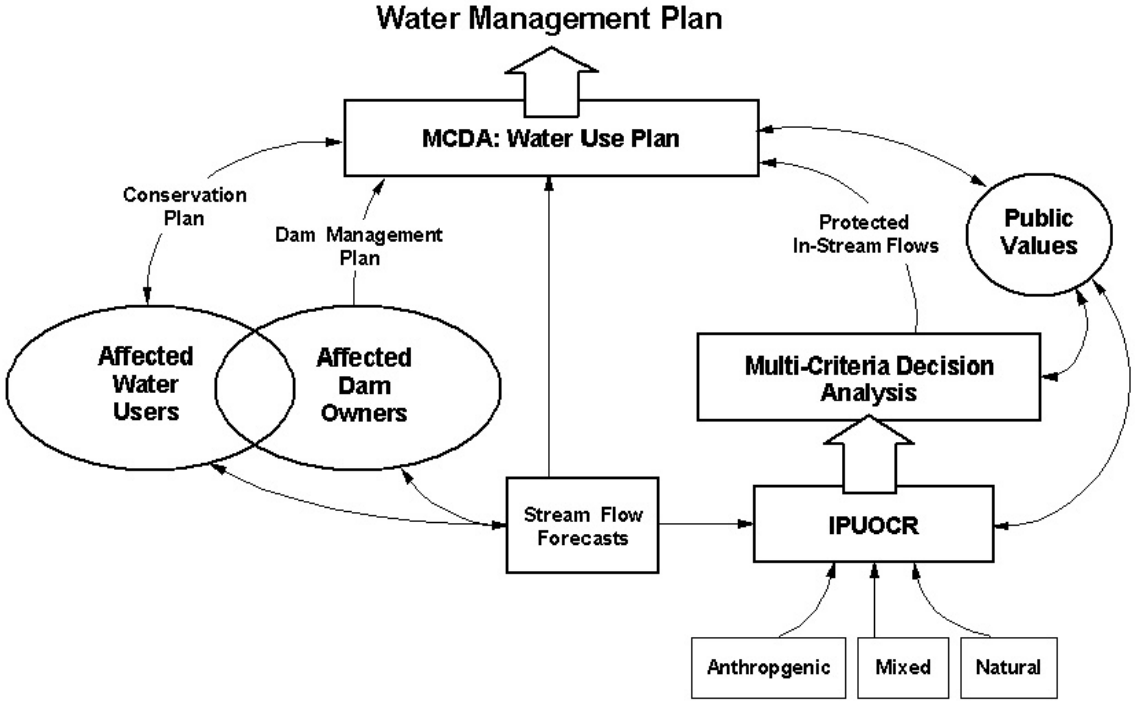
By TP Seager, SP Tuler, I Linkov and R Kay

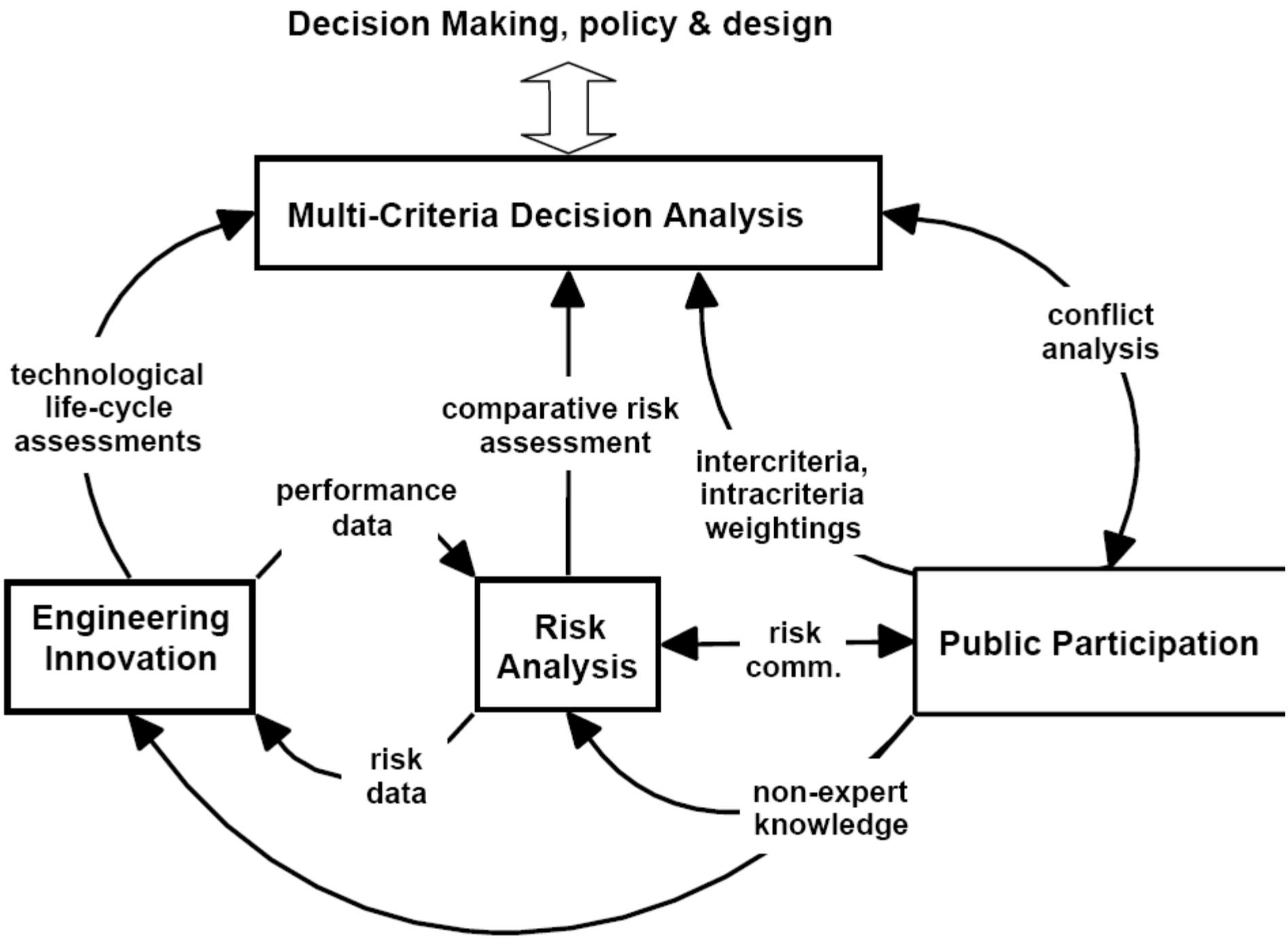




FALLFISH		
Presence (76%)		Beta
	BOULDER	1.95
	SHADING	-1.07
	DEPTH 0-25 cm	-1.76
	VELOCITY 45-60 cm/s	1.06
	RUN	-0.57
High abundance (60%)		
	Overhanging vegetation	-0.97






Decision Making, policy & design
Multi-Criteria Decision Analysis
technological life-cycle assessments
comparative risk assessment
intercriteria, intracriteria weightings
conflict analysis
performance data
Engineering Innovation
Risk Analysis
risk comm.
Public Participation
risk data
non-expert knowledge